Ground Vehicle Power and Mobility Overview

30 May 07

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Report Documentation Page

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Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Organizational Thrust Areas

Technology Thrusts:

Prime Power

- Engines
- Power Trains
- Hybrid Electric and Energy Storage
  - Drive Components (motors, generators)
  - Power Electronics

Non – Primary Power

- APU's, On Board Power Generation)
- Fuel Cells

Energy Storage

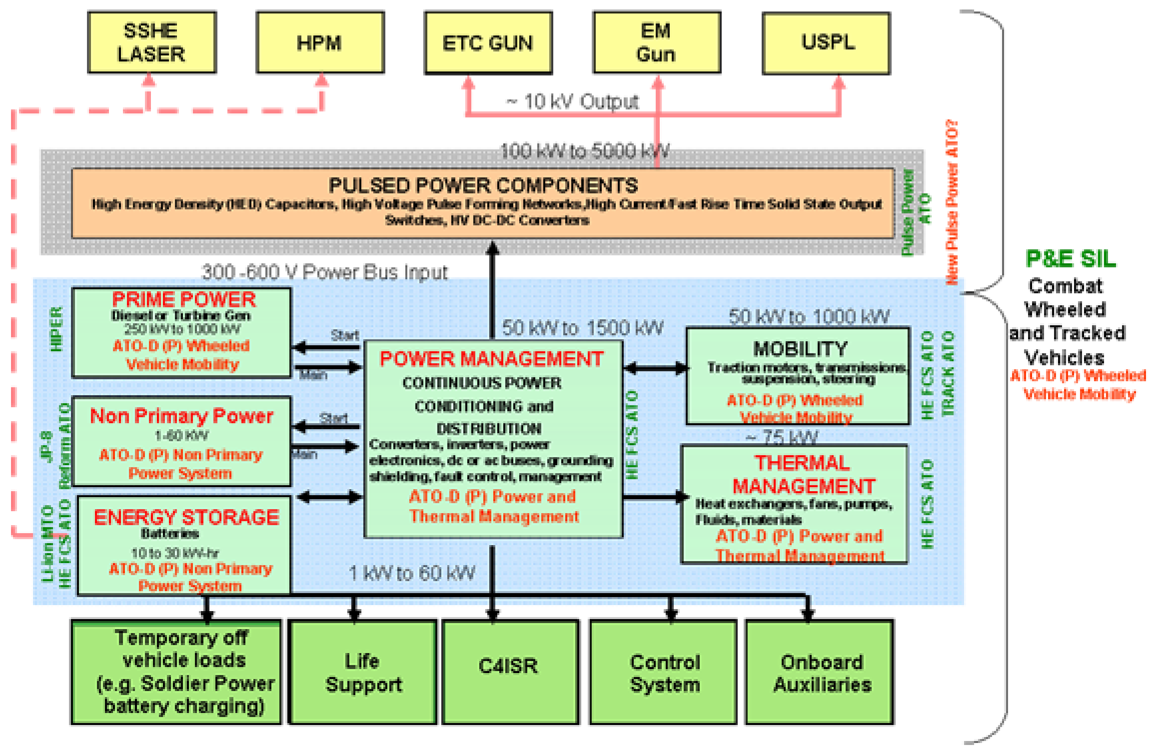
Power and Thermal Management

System Assessments

- Hybrid Electric Vehicle Assessments

Track and Suspension

- Lightweight track
- Elastomer Research
- Advanced suspension



Capabilities Thrust:

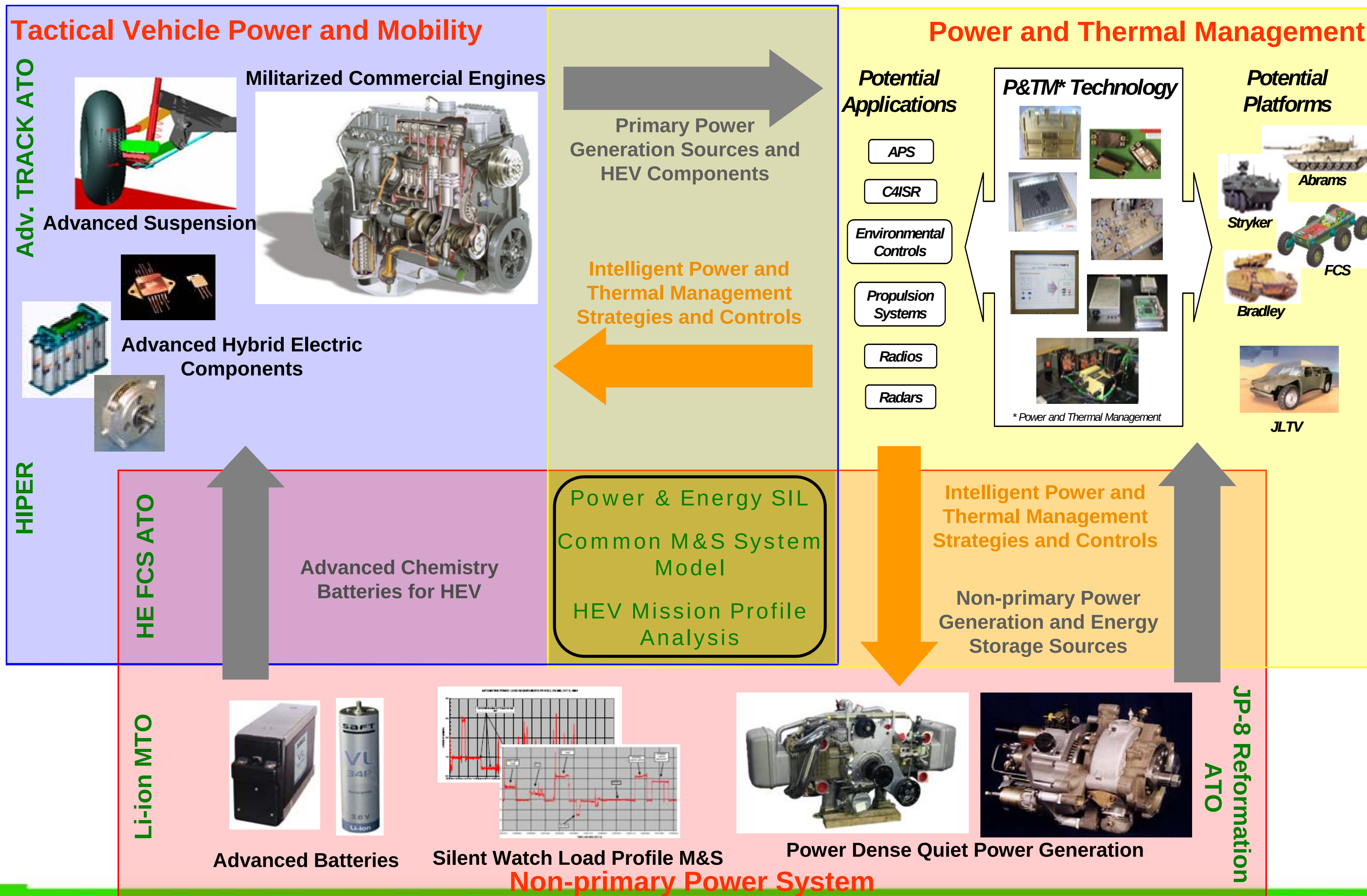
Modeling and Simulation

Testing, Evaluation and Assessment

- **Propulsion Laboratory -** Engine, Transmission, Air Filtration, Thermal and Vehicle testing, evaluation and assessments
- Future Power and Energy Laboratory
- Power and Energy SIL
- Power Management SIL
- Track and Suspension Laboratory

Ground Vehicle Power and Mobility
FY08 Proposed ATO Collaboration Strategy

Existing ATOs and Programs New ATO-D Proposed for FY08



Prime Power Technology

Problem:

Current high power commercial engines are not compact enough for future manned combat ground platforms. Future ground combat vehicles will require lighter and more efficient engines that occupy less space.

Current state of the art engines require significant development operate on one fuel forward in order to meet future tactical vehicle power and mobility needs.

Cylinder/Injector Geometry for Air Utilization

Advanced High Pressure Fuel Injection Systems

Challenges:

Diesel combustion is rate limited due to physical burn time.
Restrictive volume and weight constraints for propulsion system
Engine thermal management
Lack of combustion optimization strategy for JP-8 military version of an emission compliant commercial engine.

Key Goals:

50% improvement in combat engine power density
30% improvement in combat propulsion system power density
30% improvement in combat engine specific heat rejection
30% reduction in combat engine weight
20% improvement in tactical engine thermal efficiency
20% improvement in tactical engine specific heat rejection

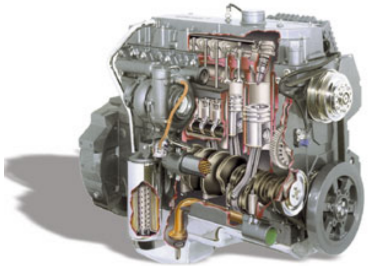
OPOC 2-Stroke Diesel Engine Tech

Key Efforts:

Opposed Piston Opposed Cylinder Engine
High Speed Combustion
Two Stage Controlled Turbocharger/Engine Development
Wheeled Vehicle Engine Development and Optimization

Customer:

PM FCS MGV BCT
PM HBCT
PEO CS/CSS



Tactical Vehicle Engine Dev and Optimization

TARDEC

Hybrid Electric Technology

Problem:

Hybrid electric systems for combat and tactical vehicles do not currently meet mobility requirements within the specified space and weight constraints. The State Of the Art power electronics operate at low temperatures resulting in large cooling system which also requires a significant amount of power from the prime mover. This also results in oversizing the engine/generator for making up the power budget loss to the cooling system

Challenges:

There are trade offs between power and torque for rotating machines. It is difficult to produce high power and high torque density from the same motor/generator. Similarly, there is a trade off between power and energy for the energy storage system. The challenge is to increase power and torque densities for traction applications and also to advance the battery systems to increase power and energy from the same source. Compact high frequency and high temperature power electronics are still in development

Key Goals:

10 kW/l and 90 N-m/l for traction motors

120 W-hr/kg and 8kW/kg for safe and reliable Li-Ion batteries

Reduce the hybrid electric drive train for combat vehicle by half its current size and weight

High power Li-Ion Cell

Key Efforts:

SIL for FCS and Wheeled vehicles

SiC MOSFET

Defect free Si/C materials

Three DC-DC converters

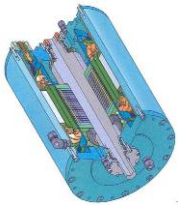
Integrated Thermal Module

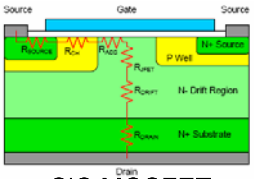
SiC power steering motor drive

High power density traction motor

Hybrid HMMWV fuel economy test


Combat and Wheeled vehicle SIL


Traction Motor



SiC MOSFET

Customer:

PM FCS MGV BCT

PM HBCT

CS/CSS –FTTS and JLTV

Non-primary Power System Technology

Problem:

Current lead-acid batteries store insufficient energy to meet Warfighter requirements for ground combat vehicle silent watch (main engine off) which range from several hours for JLTV to 24 hours for Abrams. Silent watch missions are interrupted because main engines must be re-started to recharge batteries, causing excessive fuel use, acoustic and thermal signatures.

Challenges:

Traditionally power generation (engine-generators) technologies have low power densities and high acoustic signatures.

Fuel cells are not ready for combat vehicles: Hydrogen fuel is not logistically practical; JP-8 fuel reforming is developmental, and fuel cell power units need maturation for the battlefield.

Current silent watch power requirements create unrealistic targets and need to be validated through M&S.

Key Goals:

- 40 W/kg NPS system level specific power
- 50 W/L NPS system level power density
- Undetectable at 100m in accordance with MIL-STD-1474D
- Run continuously on 3000 ppm sulfur JP-8

Key Efforts:

D.TAR.2008.02 Non-primary Power System ATO

Power Generation Efforts

R.LG.2006.03 JP-8 Reformer for Fuel Cells ATO

Reformer Risk Mitigation Efforts

Fuel Cell Risk Mitigation Efforts

JP-8 DeS Risk Mitigation Efforts

In-house efforts – NPS technology evaluation, Fuel cell evaluation and integration lab

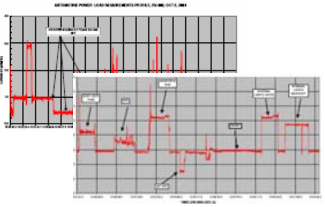
Customers:

PM HBCT, PM SBCT, PM FTS, PM FCS (BCT)

Rotary Engine APU

SOFC APU

OPOC APU

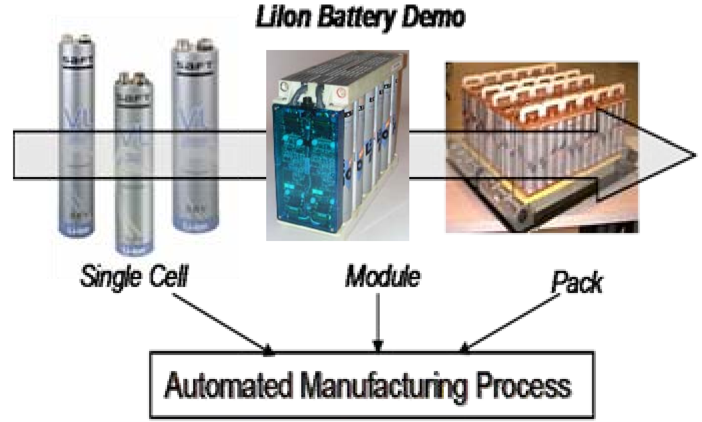


Non-propulsion Load Analysis

**(CA)-Congressional Add*

Energy Storage Technology

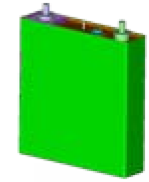
Problem:
High power Li-Ion battery pack production for FCS combat hybrid electric vehicles is costly
Li-Ion batteries for HEV dash mobility, silent watch, and pulse power for electric weapons and survivability needs to be safer and more reliable

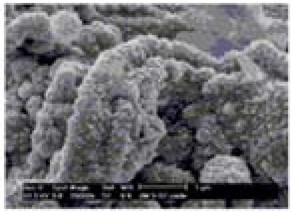


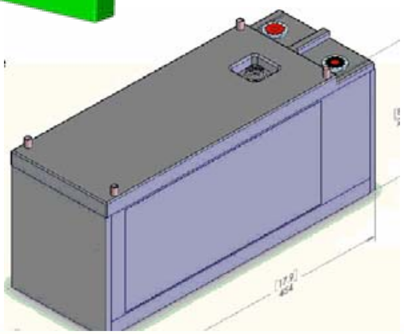
Challenges:
Understanding the thermal runaway process and its control in all sealed cells
Cell & system design optimization – power vs. energy trade-off
Manufacturing process development and cost control
Thermal Management
Cell & system safety & reliability
Power Conditioning & Integration with DC/DC Conversion
System Control& Cell Management – Battery Management System
Alternative electrochemical improvements

Key Goals:
70% improvement in power density, 30% improvement in energy density
50% improvement in cost, 50% reduction in labor hours (automated manuf. Process)

Key Efforts:
High Power, High Energy Li-Ion Battery MANTECH Program
Li-Ion Phosphate (LFP) Cathode Materials
Large Format Li-Ion Prismatic Cells and Modules with Integrated Liquid Cooling
Integrated Prototype Vehicle using Li-Ion Batteries
Battery Architecture using a Hybrid Energy Module
Thermal Runaway
Research Calorimeter
Module Test Rig
Battery Characterization

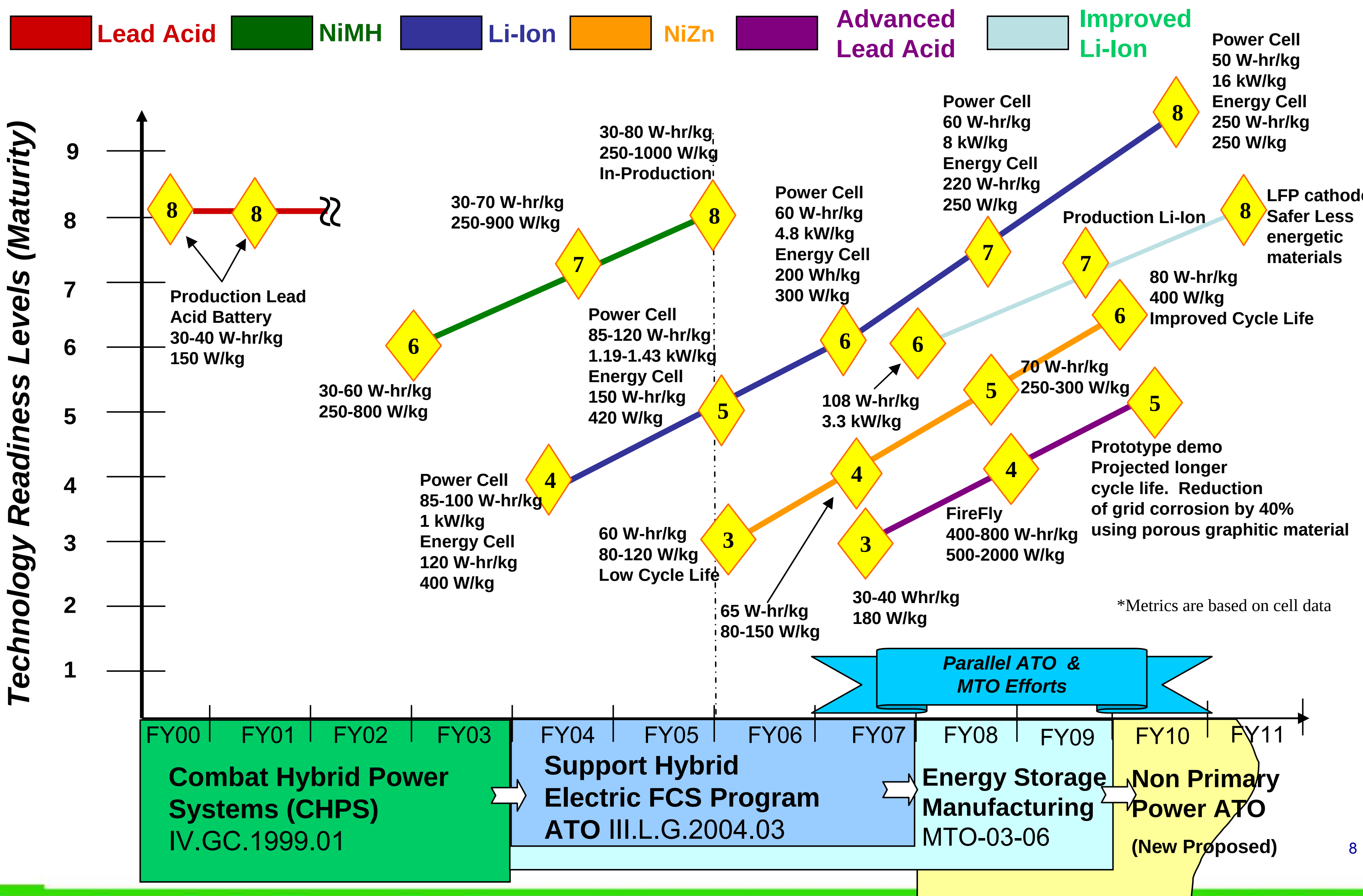




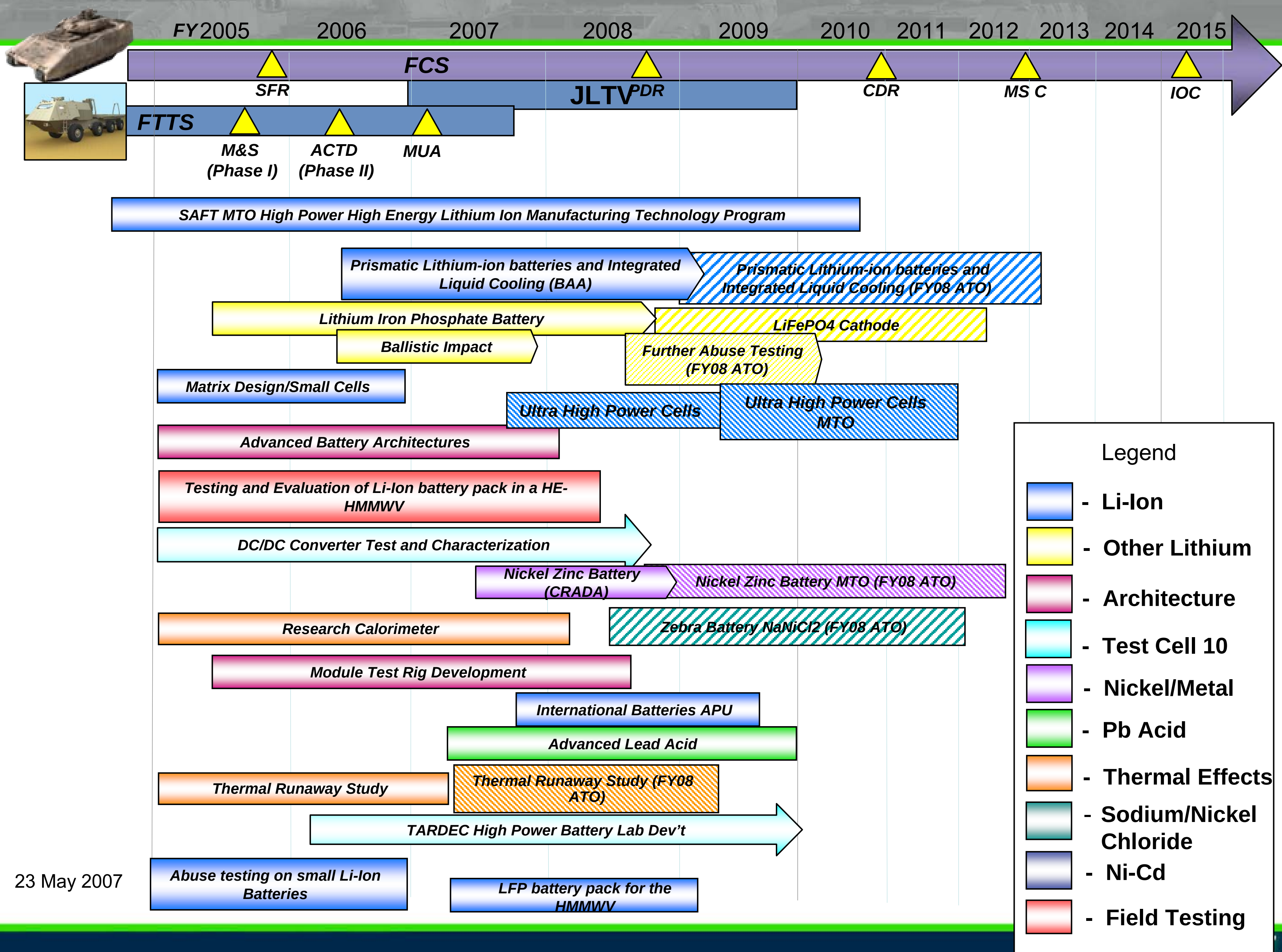


Customer:
PM FCS MGV BCT
PM JLTV
PM FTTS

TARDEC Battery Roadmap

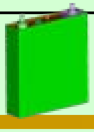
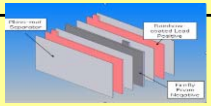


TARDEC Battery Roadmap



23 May 2007

TARDEC Battery Projects

Programs		FY07 Goals
6.2 Combat Vehicle & Automotive Technology Projects		
Experimentation and Ballistic Testing of Li-Ion and NiMH Batteries		To identify potential vulnerabilities resulting from ballistic impacts to high power density batteries 
Li-Ion Battery Electrochemical Research		**Electrolyte research**
6.3 Combat Vehicle & Automotive Advanced Technology		
Li-Ion Battery Pack for Hybrid Electric HMMWV using NCA cells		**Integrate a Li-Ion battery pack in a HE-HMMWV for testing and evaluation** 
Prismatic Li-Ion Cells with Integrated Liquid Cooling		Develop large format prismatic Li-Ion batteries and implement liquid cooling to manage the heat transfer  
MTO		
Li-Ion Battery Manufacturing Technology Objective		Automate the manufacturing process of Li-Ion batteries and improve safety and performance 
Congressionals		
HE-HMMWV Battery Pack using LFP cells		**Integrate a LFP pack into a HE-HMMWV to assess small format 26650 cells** 
Battery Test Rig		Test rig with integrated research calorimeter to allow local testing of battery modules
3D Advanced Battery Technology		**To proof out a design potential and prototype a 3D graphite/lead grid prototype for evaluation and test**
Battery Charging Technology		**Develop an intelligent battery charging system for tactical vehicles** 

Power Management Technology

Problem:

Current and future force electrical power demands exceed their power generation and energy storage capabilities.
Advanced power generation (fuel cells) and storage systems (Lithium-ion batteries) depend on sophisticated control methodologies for safe operation.
Limited fuel availability in the field.
Increasing the number and size of electrical loads on a vehicular platform increases the amount of heat generated
There is no automated way to recover from faults and induced faults (i.e. Sympathetic tripping, chain tripping of loads.)
Today's vehicular electrical architectures contain vehicle-unique electrical components which increase the logistics burden.

Challenges:

Vehicle size and weight limitations constrain power generation and storage capacity.
Ability to accurately monitor and control the power distribution to react to fluctuating loads and sources in real time has not been developed.
Lack of an open architecture for Electrical Power Architecture
Off-board power requirements are not fully defined

Software Standard

Flex cable/PCU integration

Key Goals:

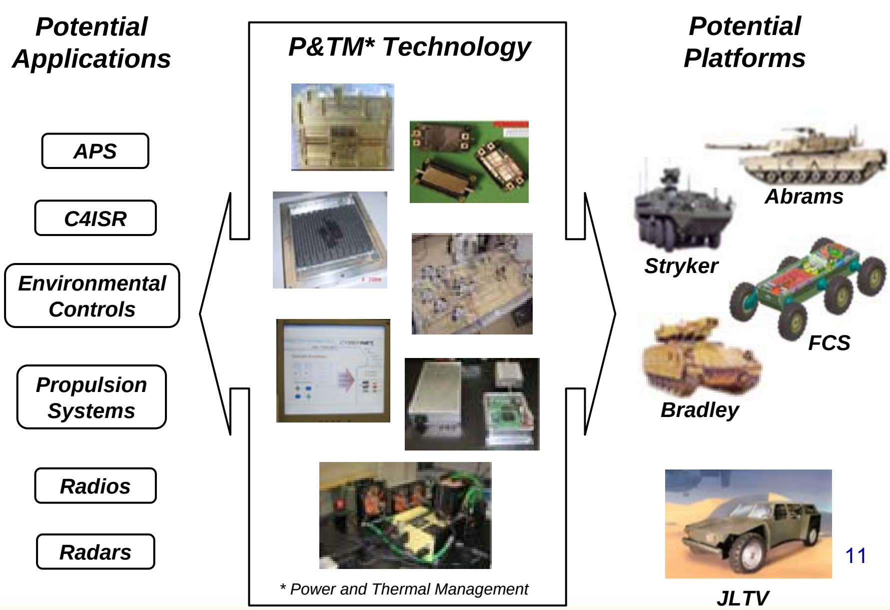
Manage power generation, energy storage, and power control/distribution components in order to maximize efficiency, increase reliability, reduce crew burden, and ensure propulsion and ancillary systems receive their required power based on crew (or robotic) input, mission derived priorities, system health, and/or tactical environment
Extend Power Mgmt Standard (FCS adopted) to include thermal mgmt
Develop Adaptive Power Mgmt for robotic platforms

Key Efforts:

Power & Thermal Mgmt ATO; PEO GCS CMPS effort
Advanced Interconnects/Cable Systems; Cognitive Power Mgmt
Electrical Power Architecture SIL; Lightweight Adaptive Control Network
Point of Use/Load Switching/Conversion; Power/Thermal Standard
SBIR: Advanced 42-volt Technologies, Vehicle Networking; Virtual SIL, Intelligent Power Control and Prognostics Harness

Customer:

PEO GCS, PM-FCS, PM-JLTV, HEV EA ATO,
TWVS ATO, NPS ATO

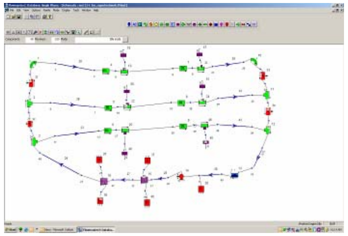


Thermal Management Technology

Problem:

Current cooling systems have insufficient capacities for projected heat rejecting requirements.
Increases in electrical power demand proportionately increase cooling system volume and weight requirements.
Thermal degradation inevitably results in reductions of component life and reliability.
Lack of intelligent control strategies for military ground vehicle thermal management systems.
Debris and contamination cause damage to vehicle powertrain components resulting in increased service requirements.

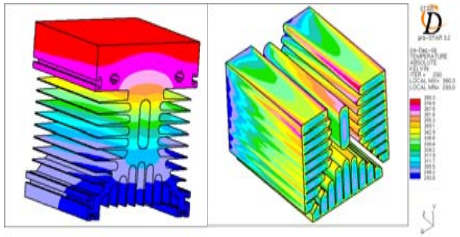
Analogous flow network model



Challenges:

Insufficient data exists on the efficiency benefits of integrating emerging technologies into ground vehicle power electronics.
Available vehicular space claims limit heat rejection infrastructure.
Improvement in capabilities/capacities for filtration (liquid and air) without increasing the system physical size.

Computational fluid Dynamics (CFD) model



Temperature distributions

Key Goals:

Increase coolant temperature into power electronics from 65C (baseline) to 80C (threshold), 100C (objective).
Increase heat flux from 89 W/cm^2 (baseline) to 350 W/cm^2 (threshold), 400 W/cm^2 (objective).
2X improvement in service life for air filtration scavenging blower motor.
3X improvement in dust loading capacity and 5X improvement on water removal capability for fuel filter.
Integrated monitoring system within oil filter for condition based service intervals.

Key Efforts:

Power and Thermal Management Technologies ATO-[R]
Advanced Inverter Cooling Demonstration
Army Research Laboratory's (ARL) work on:
- SiC, high-temperature components
- Low-Loss, Nanocrystalline Magnetic Materials
- Ceramic, Micro-Channel Heat Exchanger Development

Self Contained Two-Phase Thermal Management System SBIR

- Advanced Cooling Technologies, Shock Tolerant Capillary Two-Phase Loops SBIR
- Thermal Design/Signature Management Tools SBIR
- Liquid & Air Filtration efforts, multiple phase I & II SBIRS
  - Dynamic Air Engineering Scavenging Fan Blower Motor.
  - Real Time Engine Oil Monitoring.
  - Cross Flow Membrane Fuel Filter.
  - Dynamic Air Engineering, High Temperature Cooling Fans.
- Oak Ridge National Laboratory's (ORNL) work on:
  – Graphite Foam
  – CFD Modeling
  – Neutron Imaging
  – Rotating Heat Exchanger

Customers:

PM HBCT
PM SBCT
PM JLTV
PM FCS
PM LTV

HEVEA PROGRAM

Problem:

No holistic approach to define, evaluate, and substantiate TWV mobility requirements and specifications.

No standard Hybrid Electric Vehicle Test Methodology for TWV.

TWV duty cycles not well defined/understood; enhancing difficulty in assessing advantages and disadvantages of hybrid propulsion systems.

Challenges:

Accepted industry practices (SAE) for testing are not developed to be replicated in traditional military settings.

No industry standard advancing propulsion systems, specifications including requirements.

Key Goals:

Data and analyses to support PEO CS/CSS information requirements for JLTV MS B

M&S capability to provide a tool to predict hybrid electric drive cycle performance and fuel economy. – VPSET

HEV test methodology/Test Operating Procedure (TOP) using accepted industry practices and DOE processes. – Draft TOP validation testing ongoing.

Key Efforts: GVSL Execution of Experiments/Support - DCS

Electrical Power Architecture SIL Upgrade/Support and Thermal Management

M&S vehicle propulsion systems analysis and tool

Vehicle Testing

Customer:

PM JCSS, PM JLTV

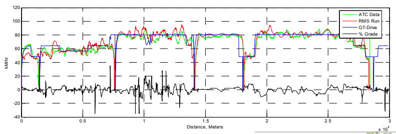
				Fuel Consumption Tests								Performance Characterization Tests					
Wt Class	Vehicle	CTA B-Course	Harford Loop	Idle Fuel	MTA SFC	PTA 2&3	Road Load	Full Load, Drawbar Pull	24V Electrical Load	Acceleration	Braking	Coastdown & Regen Braking	Electrical Energy Storage System	Physical Characteristics	Resistance to Motion	Roadway Simulator	Vehicle ID #
L	HMMWV M1113	C√(1)	C√	C	C√(1)	C	C	PC*		C*	C*	C	NA	C	C*	NA	HV-13
L	HMMWV M1152 Up-Armored	C√	C√	C	C√	C√	C√	C√	C	C	NA	C	NA	C		NA	HV-52
L	HMMWV XM1124	C√	C√	C	C√	C	C	C		C	C	C	PC	C	C	PC*	HE-2
L	RST-V GDLS	C	C	C	C	C	C	C	C	C	C	C	PC	C	C	NA	RSTV-3
M	FTTS UV AM General															NA	AMG-1
M	FTTS UV International MG															NA	INT-1
M	FTTS UV Lockheed Martin															NA	LM-1
M	LMTV, 2.5T LSAC, M1078															NA	
M	LMTV, 2.5T/FMTV M1078 LMTV												NA			NA	ESL-1
M+	HEMTT A3 OTC															NA	HA-3
M+	HEMTT A2												NA			NA	HA-2
M+	HEMTT A2 Up-Armored												NA			NA	HA-2AC
M+	HEMTT A4												NA			NA	HA-4
M+	FMTV CVT Armor Holdings, 2.5T LMTV												NA			NA	CVT
M+	FMTV M1084 MTV	PC	C		C		C						NA	C		NA	ESMC-1
M+	FMTV HE BAE Systems M1086	PC	C		C		C							C		NA	BAE
M+	FTTS MSV Armor Holdings															NA	MSV-1

Note: All pairings are part of this study, other than those designated "NA"

= awaiting response on availability to test

Key:
C = Testing Completed
PC = Partially Complete
NA = Not Applicable

Notations:
(1) = Gap in data; may do additional testing
√ = Graphical models completed, and included
* = Updated from previous reporting period



Track Technology

Problem:

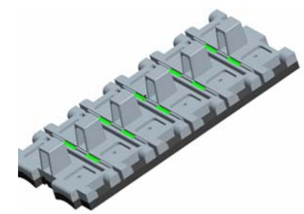
Future combat vehicles desire lightweight track with no degradation in robustness or field supportability.
Current lightweight track durability threshold at 25 ton GVW vehicles.
Current lightweight track prone to AP mine blast damage.
Elastomer components are track system life limiter of legacy track fleet.

Challenges:

Light weight track systems challenged with higher stresses / less mass which limits durability / AP mine survivability.
Natural rubber elastomers rapidly degrade under high stress / high temperature conditions

Key Goals:

40% reduction in weight
50% improvement in elastomer durability



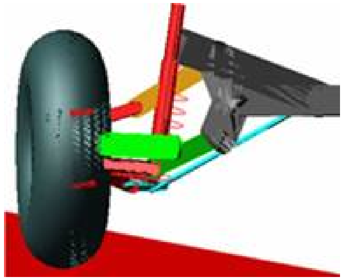
Key Efforts:

Segmented Band Track - ATO-D
Hybrid Steel Track – ATO-D
Elastomer Research Program – ATO-D
Segmented Steel Track – Congressional Add
Component Maturation Program – CMP Risk Reduction Funding

Customers:

PM FCS MGV BCT
PM HBCT

Suspension Technology



Problem:

Army Tactical and Combat vehicles require superior performance for battlefield dominance.
Up-Armoring of existing vehicle fleet challenging stock suspension components.
Developmental suspension systems maturation oversold.

Challenges:

Suspension components more complex with adaptive control.
Suspension components must be extremely robust, passive default required.
To save volume, suspension components placed outside armor protection and vulnerable to damage.

Key Goals:

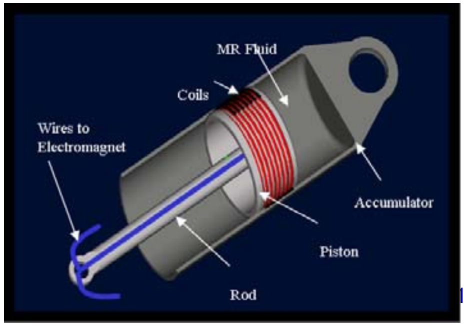
50% improvement in ride quality
50% improvement in vehicle stability

Key Efforts:

MR Suspension on Stryker – Maturation & Test, Wheeled Vehicle Power and Mobility – Proposed ATO-D
MR Suspension on Stryker - Proof of Principal Demonstration, SBIR Phase II Effort
Modular Suspension Development – Advanced Lightweight Track ATO-D
Compressible MR Fluid Development – Congressional Add
MR Suspension for Tracked Vehicle – SBIR Phase I Effort

Customers:

PM Stryker
PM FCS MGV

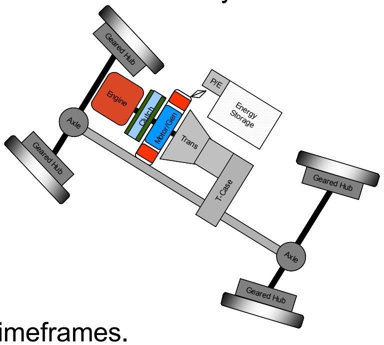


Modeling and Simulation Efforts

Problem:

Science and Technology programs, as well as Technology Insertion into fielded systems, requires accurate component and system level modeling and simulation efforts to support decision making.

The M&S community, and decision makers, need to be attentive to the correct level of fidelity and robustness required in models to identify the effects of emerging technologies on system performance.



Challenges:

Access to OEM and supplier data for model development is often difficult to obtain.

Access to performance data to use for model validation is often non-existent or costly to obtain.

Expected vehicle system usage is often unclear, making merits of future technology difficult to evaluate.

Complexities of current and future vehicle systems require multidisciplinary knowledge to support system level M&S.

Key Goals:

Develop and maintain a database of valid system level models of current fleet to support "what-if" studies within short timeframes.

Develop in-house expertise and processes to advance M&S capabilities pertaining to mobility and power system analyses.

Key Efforts:

SBIRs:

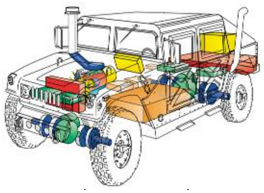
Cybernet - Vehicle/Virtual System Integration Laboratory (VSIL) for testing vehicle design prior to committing to a hardware prototype. Acquisition tradeoff studies.

PCKA - software infrastructure enabling distributed system level M&S, implementing compatibility between different simulation tools as well as protecting vendor proprietary data.

Programs:

HEVEA – Drive cycle development for fuel economy evaluation, on-board data acquisition for TWV usage histories.

P&E HSIL – M&S support for SIL operation, control system development and test management, power system modeling.



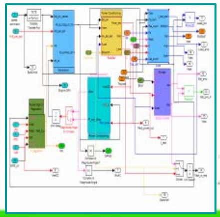
In House:

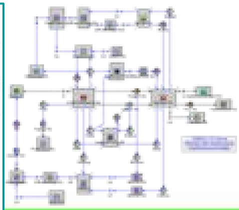
Duty Cycle Experiments – Driver-in-the-Loop, ride motion simulators

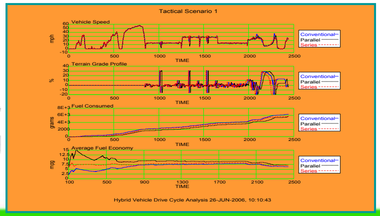
Database development – Stryker, HMMWV (M1113, M1114, XM1124), MTV (2.5-ton, 5.0-ton, Hybrid [BAE], CVT), FTTS UV, Abrams, Bradley,

Customer:

S&T Programs, PEO, ONR







Mobility Facilities

- Propulsion Test Laboratory
- Power and Energy System Integration Laboratory (SIL)
- Track and Suspension Laboratory
- Power Management System Integration Laboratory (SIL)

Propulsion Test Laboratory

10 Test Cells which include

- **6 “engine” test cells used for performance, endurance, transmission or drive train testing**
- **3 vehicle test cells designed for steady-state tests to 44000 ft-lbs per side as well as transient tests and a Power & Inertia Simulator (PAISI)**
- **Most contain portable dynamometers with absorption capability of 100-3000 horsepower**

Test Cell #9 can simulate desert heat, wind and solar conditions at full load

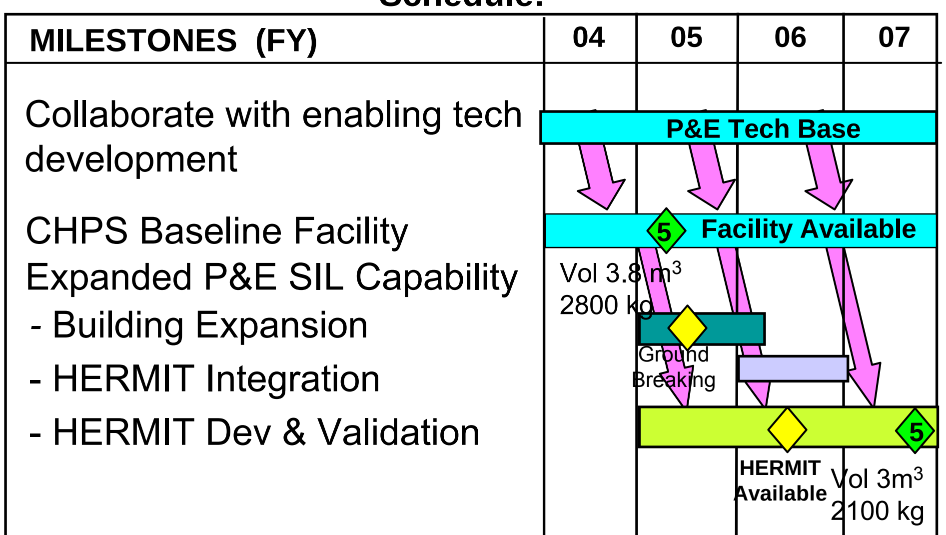
- **Ambient temperature control to 160°F**
- **Wind speeds up to 20mph in eight possible directions**
- **Two 2500 Hp dynamometers**

Test Cell #10 can test batteries, power electronics and motors to 6000rpm

Air Flow Lab has air cleaner and radiator testing capability

Power and Energy SIL

Schedule:



Purpose:

- *Integrate and evaluate power and energy technologies and subsystems from advanced tech base programs in a user-like lab environment.*

Product:

- *Compact integrated system that will provide efficient spin-out power and energy generation and management, including pulse power. Enables "Form, Fit, and Function" testing of power and energy technologies.*

Payoff:

- *Comprehensive power distribution and control capability in a real vehicle environment.*
- *Compact lightweight power and energy system with enhanced deployability through reduced volume and weight.*
- *Lowers technical risk for both technology developer and vehicle integrator.*

New Power and Energy Lab

Design/Build request RFP being developed

<u>Improved/Introduced Laboratories:</u>

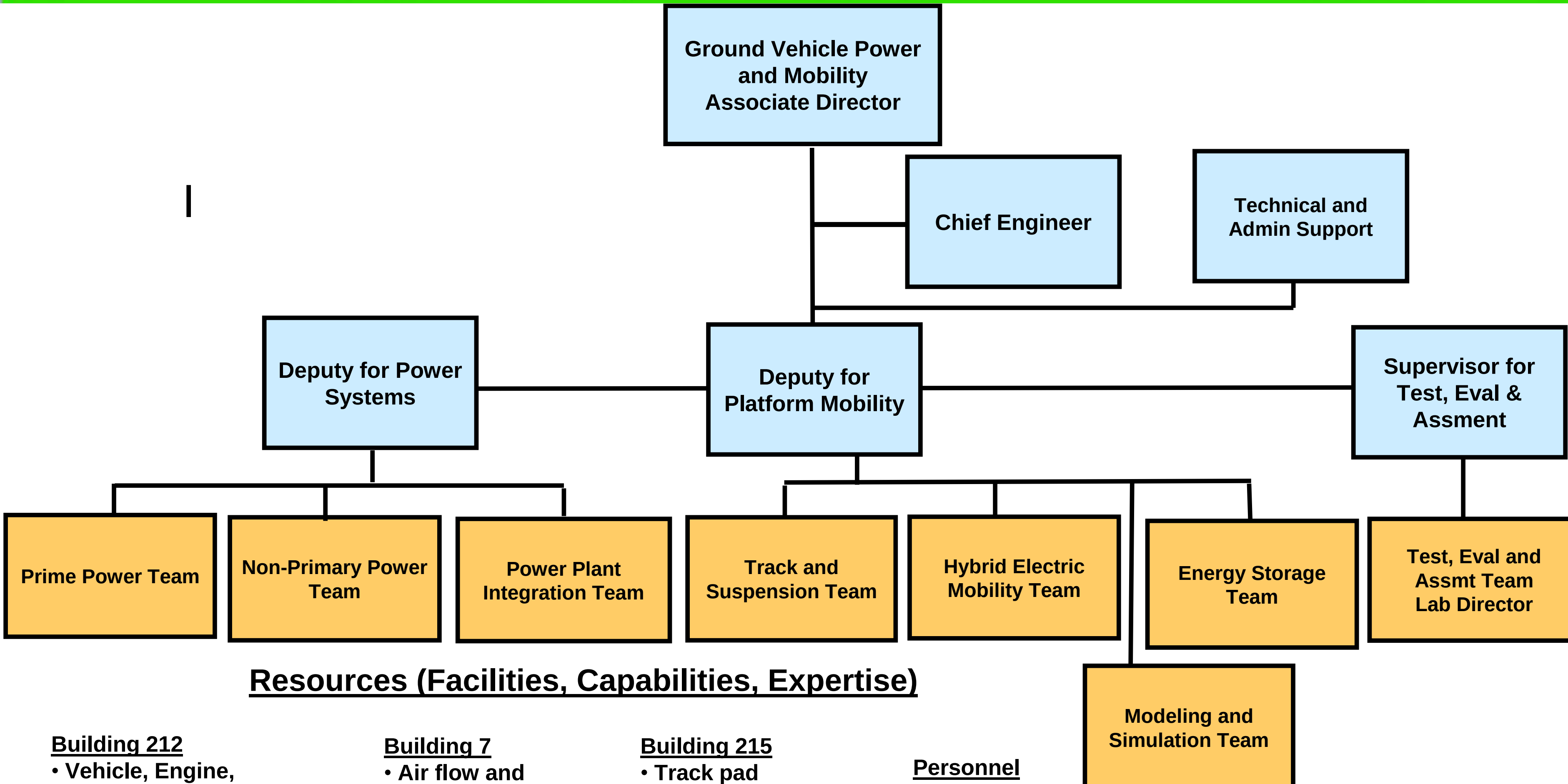
- Power and Energy Laboratory
  - New Capability for hydrogen/JP-8 fuel cell reformation testing
  - Improved alternator and starter testing capability by 20% over current capabilities
  - New Capability to test hydraulic systems
  - New Capability for air conditioning component testing
  - New Capability for capacitor DC life testing
  - New Capability Pulse formed Network system integration and testing
  - Improved capability to test large motors and power electronics by 2x current capability
- Airflow and Thermal laboratory
  - Improved air flow capability by 3x current capability
  - Improved thermal capabilities by 3x current capability
- Multipurpose Room
  - New Capability: Multi Wheeled vehicle testing with environmental capability from -60°F to 160°F
  - New Capability: Hybrid Electric Vehicle System Evaluation

<u>Push for "GREEN"</u>

- TARDEC is guiding the design to maximize energy conservation and use of alternative energies, materials, and other aspects of building design
- Goal is to attain Leadership in Energy and Environmental Design (LEED) gold/platinum certifications

Back up

Organizational Overview



Resources (Facilities, Capabilities, Expertise)

Building 212
- Vehicle, Engine, transmission, APU, batteries, generators, and motor testing
- Environmental heat management chamber and lab
- Steady state and transient test cells and labs

Building 7
- Air flow and coolant test cells and lab
- Fuel Cell/Battery testing capability

Building 215
- Track pad abrasive testing capability
- Track blowout testing capability
- Track pin deflection machine

Personnel
- 72 Engineers
- 13 Technicians
- 11 contract Engineers and Technicians

Applicable S&T programs to Robotic Vehicles

Mobility Power & Energy Thrust Areas

Power Systems
Engine
Fuel Cells
Air, Thermal and Power Management
Power Trains
Non – Primary Power Systems
(APU's, On Board Power Generation)

Platform Mobility
Hybrid Electric Drive Components
Power Electronics
Energy Storage
Lightweight track
Elastomer Research
Advanced suspension
Modeling and Simulation

Testing, Evaluation and Assessment
Propulsion Lab, Air and Cooling Lab
(Future Power and Energy Lab)
Vehicle Testing and Experiments

Key Platforms

PM FCS

Robotic

PEO-GCS

PEO-CS/CSS

Key Power & Energy Technologies for Robotics

PEM, SOFC Fuel Cells
System and Component Thermal Management
Power monitoring, improved diagnostics,
fault management,
automatic/semi automatic load control,
Auxiliary Power to include
small IC engine, small generators

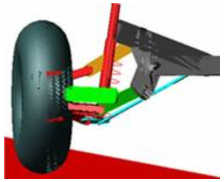
Drive Motors/Generators
Converters/Inverters
Advanced Batteries
(Li-ion,Ni-mh)
Capacitors

Band Track
Hybrid Steel Track
MR Suspension
Semi Active Suspension

Mobility M&S
Laboratory and vehicle
Evaluation and testing

Requirements - Functional Decomposition

Non Primary Power



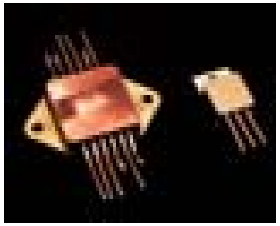
Advanced Suspension

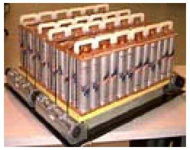
- **Ground Vehicle Power and Energy**
  - **Prime Power**
    - **Engine**
      - Diesel
      - Turbine
      - Gasoline
      - Stratified Charge
    - **Drivetrain**
      - Electrical
      - Mechanical
      - Driveline Components
      - Mobility Components
  - **Non Primary Power**
    - Diesel
    - Turbine
    - Fuel Cell
    - Battery
    - Generators
  - **Energy Storage**
    - Batteries
    - Capacitors
    - Flywheels
    - Fuels
  - **Power & Thermal Management**
    - **Power Management**
      - Power Generation
      - Energy Storage
      - Power/Thermal Control & Distribution
    - **Thermal Management**
      - Power Plant Cooling
      - Power-Electronics Cooling
      - Climate Control

JP8 Reformer

Militarized Commercial Engines

Hybrid Components

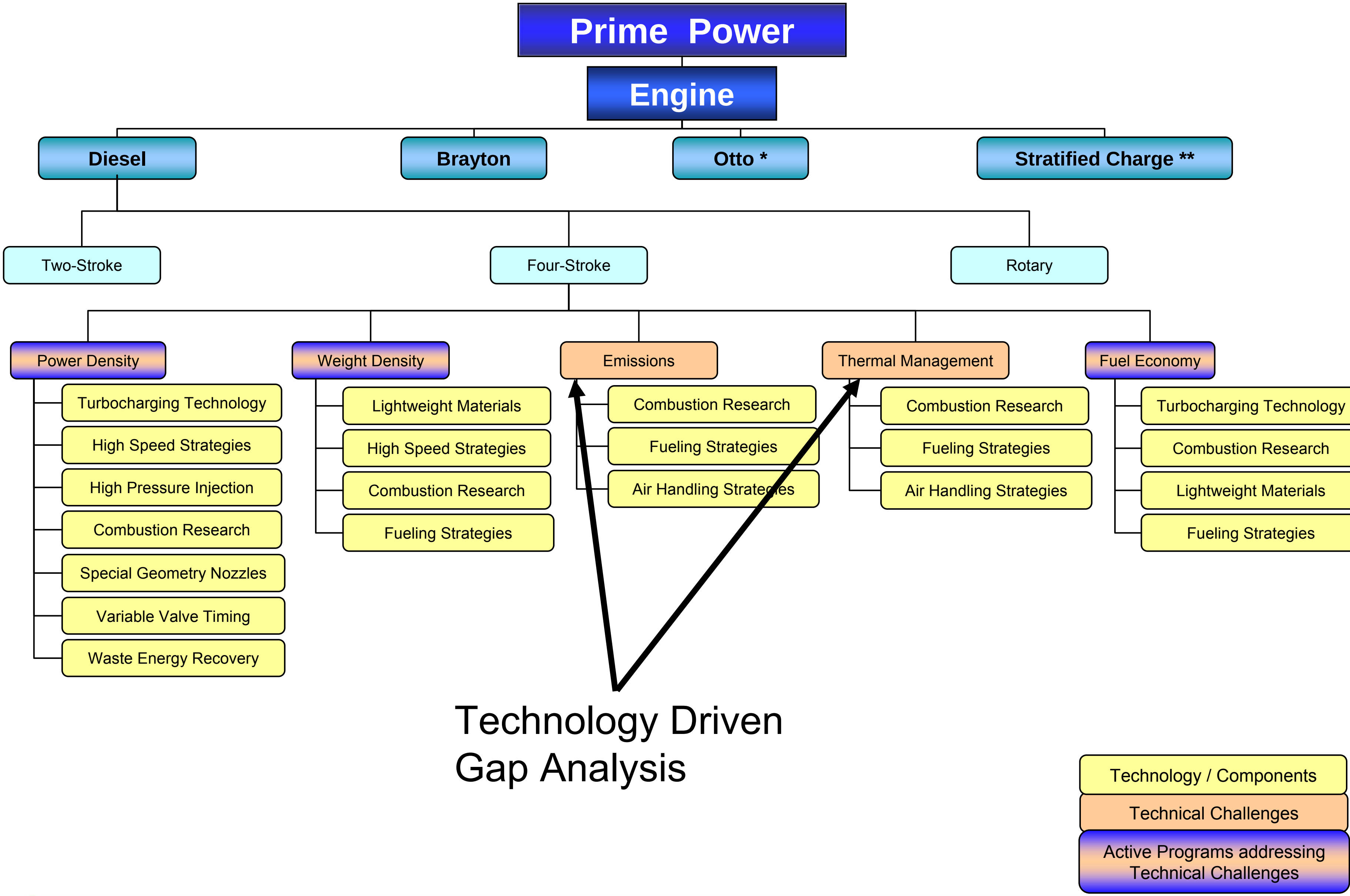




Energy Storage

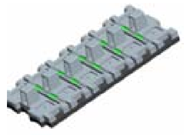
Power Dense Quiet Power Generation

Requirements - Functional Decomposition



Current Power and Energy Programs

Primary Power


S&T Programs – FY07

- High Performance Engine (HIPER)
- Hybrid Electric (HE) for Future Combat Systems (FCS)
- Advanced Lightweight Track
- Automotive Research Center
- Ceramic Metal Matrix Composites
- Segmented Steel Track
- Lightweight Roadwheels

- Advanced drivetrains for enhanced mobility
- PEM Fuel Cells for Medium Duty Vehicles
- Next Generation Non-Tactical Vehicle Power
- Hydraulic Hybrid Research (HAMMER)
- Low Temperature Vehicle Research
- Compressible Magneto Rheological Fluids

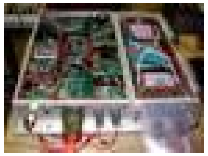
Non-Primary Power



- JP8 Reformation
- Development of Logistical Fuel Processor
- Defense Transportation Energy Research
- Plasma JP-8 Reformer
- Solid Oxide Fuel Cell Materials
- Fuel Cell Ground Support Equipment
- Rotary APU

Energy Storage





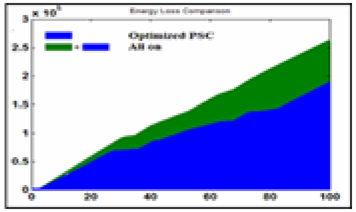
- Experimentation and Ballistic Testing of Li-ion and Ni-Mh Batteries
- Li-ion Battery Pack for Hybrid Electric -HMMWV
- Prismatic Li-ion Cells with Integrated Liquid Cooling
- Li-ion Battery Manufacturing Technology Objective
- Li-ion Battery Electrochemical Research
- Pulse Power Components
- HMMWV Battery Pack
- Battery Test Rig

- 3-D Advanced Battery Technology
- Battery Charging Technology
- Solid Hydrogen Storage
- Military Fuel Research Program
- Advanced Microgrid Liquid Fueler
- Transportable Syntheic Fuel Manufacturing Modules
- Fire Resistant Fuels

6.1 / 6.2 / 6.3
Congressional

Current Power and Energy Programs

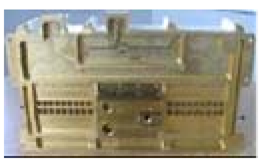
Power Management



S&T Programs – FY07

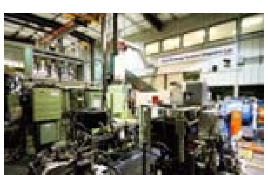
- Cognitive Power Thermal Management Algorithms
- Electrical Power Architecture (EPA) SIL

Thermal Management



- Foam Heat Exchanger
- Integrated Heat Sink Micro-Channel
- Use of Graphite Foam as a Cold Plate for Heavy Hybrid Propulsion Systems
- Advanced Inverter Cooling Demonstration
- Advanced Thermal Management Controls

System Assessments



- Power and Energy System Integration Labs (SIL)
- Hybrid Electric Vehicle Evaluation & Assessment (HEV EA)
- 21st Century Base
- HMMWV Hybrid Technology Conversion Kits
- Maturation and User Evaluation of Hybrid Electric XM1124 HMMWV's

6.1 / 6.2 / 6.3
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